Dominick V. Rosato

Rosato's Plastics Encyclopedia and Dictionary

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having a symmetrical cross section that is square or rectangular with sharp or rounded corners or edges, or is round, hexagonal, or octagonal, and whose diameter, width, or greatest distance between parallel faces is less than 3/8 in. (9.52 mm).

extruder The extruder, which offers the advantages of a completely versatile processing technique, is unsurpassed in economic importance by any other process. This continuously operating process, with its relatively low cost of operation, is predominant in the manufacture of shapes such as films, sheets, tapes, filaments, pipes, rods, in-line postforming, and others. The basic processing concept is similar to that of injection molding (IM) in that material passes from a hopper into a cylinder in which it is melted and dragged forward by the movement of a screw. The screw compresses, melts, and homogenizes the material. When the melt reaches the end of the cylinder, it usually is forced through a screen pack prior to entering a die that gives the desired shape with no break in continuity (see Fig. below).

A major difference between extrusion and IM is that the extruder processes plastics at a lower pressure and operates continuously. Its pressure usually ranges from 1.4 to 10.4 MPa (200 to 1,500 psi) and could go to 34.5 or 69 MPa (5,000 or possibly 10,000 psi). In IM, pressures go from 14 to 210 MPa (2,000 to 30,000 psi). However, the most important difference is that the IM melt is not continuous; it experiences repeatable abrupt changes when the melt is forced into a mold cavity. With these significant differences, it is actually easier to theorize about extrusion and to process plastics through extruders, as many more controls are required in IM.

extruder-adapter ▷ **die adapter**

extruder, adiabatic A method of extrusion in which, after the extrusion apparatus has been heated sufficiently by conventional means to plastify (melt) the material, the extrusion process can be continued with the sole source of heat being the conversion of the drive energy, through viscous resistance of the plastic mass in the extruder. Also called autothermal extrusion and autogeneous extrusion.

extruder air entrapment ▷ **air entrapment**

extruder barrel or cylinder ▷ **barrel**

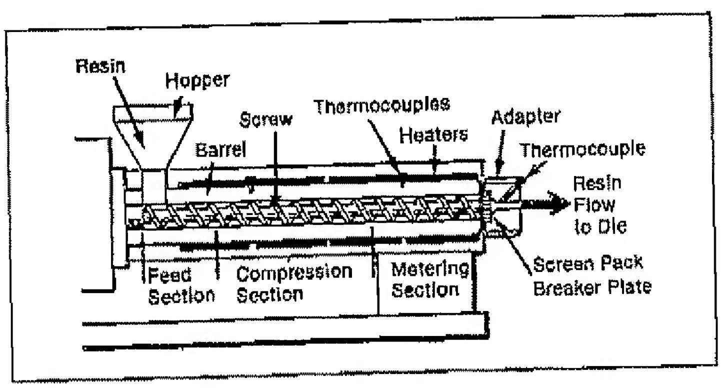
extruder barrier screw ▷ **screw, barrier**

extruder base or stand The metal structure on which are mounted the basic extruder components such as barrel, thrust housing, gear pump, etc.

extruder blow molding ▷ **blow molding, extruder**

extruder, blown film More plastics go through blown film lines than other extrusion lines. The process can vary in direction (up, down, or horizontal) and in the method of flattening the film prior to wind-up (see Fig. on p. 241). Developments in these lines relate to the extruder, dies, takeoff systems, and automation components. The development of new high-speed extruders with a grooved feed zone and barrier screws makes it possible to increase output while providing processing flexibility—which, particularly in coextrusion, renders changes of screws unnecessary. Blown film dies have been developed with the goals of low pressure consumption, good self-cleaning, material changes, and ease of maintenance. The automation of blown film plants to reduce film thickness tolerances involves the increased use of linear weight control systems (upstream and downstream), as well as greater opportunities to influence profile thickness via suitable control elements on the die and cooling systems.

Regarding the film direction, horizontal operation entails no overhead installation and a low building height, but requires a larger floor space with probable adverse effects of gravity



Cross section schematic of a single screw extruder.

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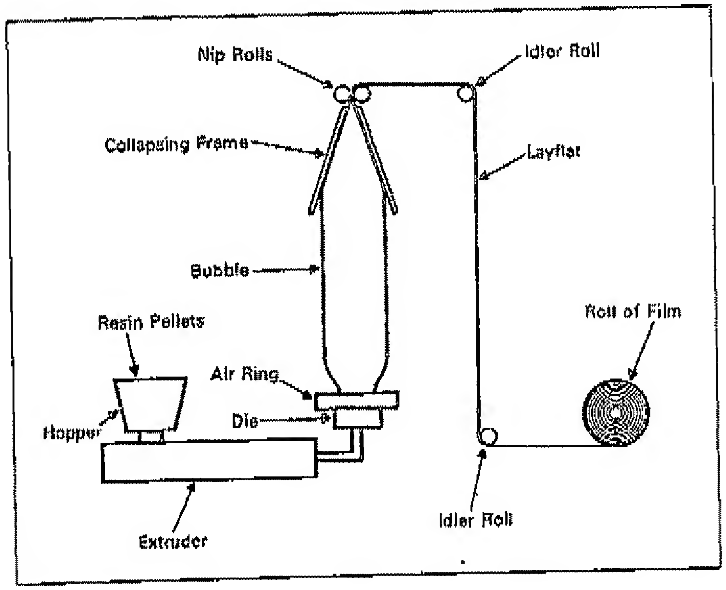


Schematic of a basic, vertical-up, extrusion blown film line.

and uneven cooling. Vertical-down operation has the advantage of start-up without flooding of the annular die gap by exiting hot melt. However, vertical-up operation is the usual method, provided sufficient melt strength exists for an upward start-up, and so on. Special die blow heads are designed, with (usually) a multiple threaded helical mandrel discharging into an expansion space. The tubular melt assumes its final shape in a "smoothing-out" zone, which in all heads is a cylindrical land in a parallel position between the mandrel and the orifice. Its length is about 10 to 15 times the annular gap width (the lower value applies to thin film and the higher to thick film). The gap width is generally 0.5 to 2.0 mm.

extruder blown film air ring A circular manifold used to distribute an even flow of air onto a hollow tubular film (bubble) passing through the center of the ring as it exits the die. The air cools the film uniformly to aid in producing an even film thickness and speeding up the production line.

extruder blown film bag manufacturing ▷ **bag manufacturing**

extruder blown film blocking ▷ **film blocking**

extruder blown film blow up ratio Blow up ratio is the ratio of the final diameter (before gusseting, if any) to the original die diameter opening. It usually ranges from $1\frac{1}{2}$ to $4\frac{1}{2}$; depends on type material, type die, speed of line, etc.

extruder blown film "frost" line With certain plastics, such as polyethylene, a line or ring-shaped zone located at about the point where the film initially reaches its final diameter. This zone is characterized by a "frosty" appearance to the film caused by the film temperature falling below the softening range of the plastic. The frost line is not always visible so, for practical purposes, it is defined where the final diameter is reached. When visible, the line should be level. Its height above the die is an important factor. The higher it is, the more critical gauge control becomes. The frost line is essential for controlling molecular orientation of the melt in the machine and transverse directions, thus influences some physical properties such as tear, tensile, and impact strengths.

The frost line can be raised or lowered by means of extruder output or take-off speed. However, the preferable way of adjusting the height of the frost line is by means of the volume of cooling air blown against the bubble. When the screw speed (and resin output) goes up, the distance between the die and the frost line is increased. When more cooling air is blown against the bubble, the frost line drops; a decrease in cooling air causes it to rise.

Raising the frost line gives the film more time to solidify, resulting in a smoother surface and higher clarity and gloss. However, too high a frost line may cause the film to block (stick) when rolled up.

A too high frost line may result in the film sticking to the nip rolls. This becomes less of a problem if the nip rolls are high above the extruder and if water of about 27°C (80°F) is circulated through the driven stainless steel nip roll.

The frost line must always be as level as possible. The primary cause for a rising or dropping of the frost line in spots may be improper adjustment of the die opening. This may cause variations in film thickness, non-uniform film cooling and a non-level frost line. A non-level frost line may also be caused by uneven cooling around the air ring.

extruder blown film gauge distortion Gauge thickness can be extremely nonuniform due to melt flow behavior on exiting the die and/or distortions of the collapsing frame. To provide uniformity, rotating dies or oscillating film hauloffs are used. Each of these systems have different technical approaches. As an example, rotations could be oscillating 180° or rotating platform 360° with action in different positions (horizontal, vertical, etc.). The different systems available meet different requirements such as web width, cooling system effect, degree of tacky or stiff material, line speed, and/or gauge thickness, particularly with thin-gauge versus width of web.

extruder blown film internal cooler IBC provides additional cooling advantages for the film traveling from the die to the nip rolls; further improving total cooling with the air ring. Its success depends on factors such as providing a smooth, controlled exchange of internal air and to maintain tight tolerances with respect to bubble geometry.

extruder blown film nip rolls A pair of rolls situated at the top (or bottom) of the tower which close the blown film envelope, seal air inside of it, and regulate the rate at which the film is pulled from the extrusion die. One roll is usually covered with a resilient material, the other being bare metal with internal cooling means.

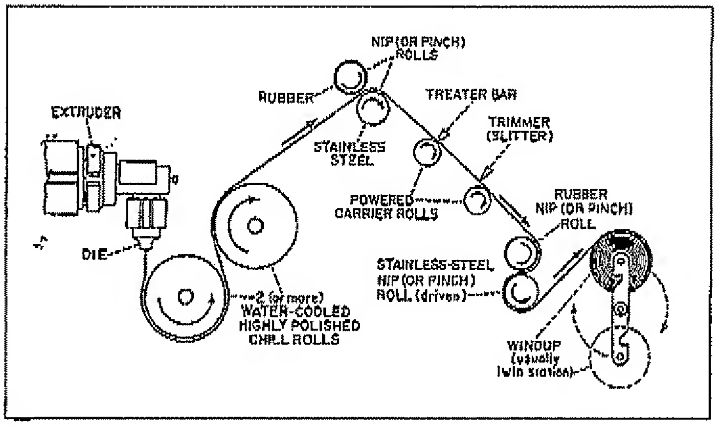
extruder blown film oscillating or rotary die ▷ **extruder blown film gauge distortion**

extruder blown film selection of machine The output rate of extruders is largely dependent upon the type of screw used, L/D ratios, horsepower available, the screw speed (rpm), the type of barrel cooling used, and the back pressure of the melt in the barrel. The following summarize these parameters and their influence on output rate: (1) *Screw type* The trend of the industry has been to long metering section screws (8 to 10 turns are standard). This type of screw offers better shearing of the melt and a better film quality. (2) *L/D Ratio* An L/D ratio must be selected which will allow a proper "dwelltime" (residence time) of the melt in the barrel. 24:1 L/D and larger are standard. Note there is a possible upper limit to the L/D above 30:1 where the screw becomes too weak to support the applied torque. (3) *Horsepower* The trend has been to increase the drive horsepower along with the L/D ratio to up the output rate. A general rule of thumb is that 6 lbs per hour output can be expected per applied horsepower. (4) *Screw Speed* Speeds continue to increase to obtain the maximum output of acceptable film. (5) *Liquid Cooling* Becomes more important for the larger extruders. Cooling requirements increase as longer screws and higher speeds are used. The frictional heat which is developed lowers power costs but must be controlled effectively. (6) *Pressures* Pressures for blown film extrusion should range in the neighborhood of 3,000 to 4,000 psig when good die design and streamlined melt flow are used. Note: an extruder barrel is usually rated for 10,000 psig maximum pressure. However, one should not exceed 5,000 psig for reasons of safety.

extruder blown film stretching-orienting The blow up ratio determines degree of circumferential orientation and the pull rate of the bubble determines longitudinal orientation. With the proper orientation blow up ratio and temperature profile, increased film performance develops. ▷ **orientation** and **extruder film orientation**

extruder blown film tower Apparatus for handling film between the extruder die and take-up equipment. The blown film tube (bubble) passes through the tower where it is cooled and the size and gauge are regulated. At the top, or near the end, the sides converge, collapsing the bubble prior to winding.

extruder blown film wrinkles Wrinkles are problems which have always plagued extruders. They can occur intermittently and are annoying and costly. Badly wrinkled film rolls must be scrapped. Wrinkling on the windup roll may be caused by conditions such as frost line too high and/or die ring out of adjustment. Bias is a condition where the two halves of the tube circumference are unequal. This causes excessive friction at the guide rolls or forming tent or unbalanced pull at the nip roll, resulting in ruffle-like wrinkles across the center of the lay-flat width of the wound roll. Film may be too cold when it reaches the nip rolls and its stiffness may cause crimping at the nip. Use of higher density plastic will increase the stiffness and its susceptibility to wrinkles. The guide rolls may not be properly aligned with the nip rolls. The use of spreader or expander rolls is often helpful in removing wrinkles caused by uneven or too high web tension. Surging of the extrudate and air currents in the shop are detriments



Schematic of flat-film extrusion line using chill rolls.

extruder film In addition to extruded blown film, there is extruded flat film. Flat film is extruded directly by using cooling rools, quench water bath, or both. The cooling roller system is also called chill roll or cast film. Flat films processed through slit dies are cooled principally by using chilled rolls. Many different resins are used, with thicknesses ranging from 15 to 200 μm (see Fig. above). Alternatively, certain plastics go directly into a water tank, but that creates many technical difficulties in production. Thus, the chill roll process is preferred; and film up to 3 m in width will have output rates of at least 120 m/min.

In this process, the melt film contacts (as quickly as possible, vertically or at an angle) the first water-cooled highly polished (to 1 μm) chrome-plated roll. An air knife can be used; its placement parallel to the die makes it possible to press the film smoothly onto the first cooling roll by means of a cold air stream. Lubricant plate-out on the cooling rolls is avoided by operation with contact rolls. At haul-off rates of up to 60 m/min, reel change is carried out by hand. At higher rates, automatic changeover equipment is required.

Advantages of the chill roll process (vs. blown film) include: preparing almost transparent film from crystalline resins (the frost line forms about 50 mm above the contact line with the chill roll); no risk of blocking; a simple crease-free wind-up; continuous film thickness control; high output; relatively small space requirement; and the fact that pretreatment for printing can be applied simultaneously to both sides of the film. Disadvantages are: the limitation on maximum width of about 3 m (blown film layflat is at least up to 12 m); loss through edge trimming; and basically only uniaxial orientation. ▷ **extruder film quench-tank**

extruder film arrowhead Lines meeting at a rounded angle. They point in the direction of extrusion.

extruder film blocking ▷ **film blocking**

extruder film bowed rolls ▷ **bowed rolls**

extruder film brittleness Film brittleness is the tendency of a plastic, such as polyethylene bags, to split along a fold, crease, or gusset or across the bag face when rapidly stressed. This property depends mainly upon plastic density and molecular orientation. Films made of lower density are less brittle than films of higher density plastics. Film made of plastic of lower melt index is also slightly less brittle than higher MI. A narrow molecular weight distribution has favorable influence. Since film brittleness also depends on the structural orientation, it may be quite different in the machine direction versus the transverse direction. Flat film, especially when extruded at a high take-off speed, is oriented more in the machine direction. Most blown film is also oriented more in the machine direction, although to a lesser degree than flat film.

extruder film brittleness temperature test The temperature at which a plastic becomes sufficiently brittle to break when subjected to a sudden blow (ASTM D 746).

extruder film capping The Fig. shown under ▷ **extruder coating** is an example of capping or laminating a substrate (paper, aluminum foil, plastic, fabric, etc.).

extruder film clarity Most film producers desire a product with high clarity and a minimum of haze or frostiness. Clarity is imperative in the packaging field where transparency of the package enhances the sales appeal of wrapped articles. However, film clarity can vary considerably with extrusion processing conditions; different optical properties can be achieved.

extruder film cooling roll versus quench-tank In chill roll or cast film extrusion, the heat extruded through the die slot is cooled by the surface of two or more water-cooled chill or